Comparative analysis of the performance of rope-pump and standardized handpump water systems in rural communities of the Northern and Upper East Regions of Ghana

Abstract

Ground water systems form essential components of rural water supply. In Ghana, four handpumps, namely Afridev, India Mark II, Nira AF-85, and Vergnet have been standardized for rural water supply. However, they have failed to deliver satisfactory levels of sustainability, largely due to inadequate maintenance capacity. An alternative to standardized imported handpumps is the locally manufactured rope-pump, which is considerably cheaper and easier to maintain but has not been standardized for use in Ghana for rural water supply. Framed from the Technology Acceptance Model (TAM), the post-positivist paradigm and quantitative research approach, this study compared the performance of rope-pumps with standardized handpumps, to determine whether rope-pumps technology provide viable alternative for rural water supply. Probability sampling and self-designed questionnaires were used to elicit data from 431 respondents. Descriptive statistics, correlations and independent sample t-test were utilized to analyze the data. Decision rule applied in testing the hypothesis (H_o) with 95% confidence interval was: accept H_o, if p-values are $> \alpha = 0.05$ and do not accept H_o if p-values are $\leq \alpha = 0.05$. Findings showed rope-pumps as a potentially viable option to standardized handpumps. There were no significant differences between rope-pumps and standardized handpumps with respect to robustness, sustainability and microbiological quality of water delivered by the two pump types. Rope-pump technology is feasible, sustainable, scalable and will likely meet user needs if standardized and adapted for use by the communities. Measures for technology adaptation, government subsidies, investments, pollution control and standardization are necessary and will remarkably improve water quality from rope-pumps installed in the communities.

Keywords: *Rope-pump and Handpump; Sustainable Rural Community Water Supply; Water Quality; Northern and Upper East Regions; Ghana.*

1. Introduction

Water, an essential commodity in the lives of humans, has been a problem to most of the rural masses. The standardized pump is a pump which has been in use for groundwater supply for a very long time in the country. Its mechanism of drawing groundwater is by pump and suction which forces water to rise to the surface through the tubes connected to the pump. The rope-pump comprises of a wheel and handle connected to a rope with washers and used to draw water from a well or a borehole. Globally, the use of rope and handpumps have become increasingly essential because prolonged dry seasons experienced by rural poor communities and villages adversely affect the availability of rainwater or runoff and ground water resources including boreholes, wells or springs, which could serve as a buffer for short-term environmental variability and evaporation of surface water resources (MacDonald & Calow, 2007). As a result of climate variabilities, the rainfall patterns across Africa have been highly variable. Droughts are becoming endemic in sub-Saharan Africa and the extent of drought-affected areas is increasing (Sheffield & Wood, 2008). There is observed increase in water demand during droughts in Southern Africa in the early 1990s (Calow et al., 1997), droughts in West Africa, East Africa and the Horn of Africa (Calow et al., 2009). In periods of prolonged drought, pipe-born systems easily breakdown, borehole water levels and quality reduce rapidly, “surface water and shallow unimproved groundwater sources (shallow wells and small springs) often fail, leaving only water points abstracting from larger groundwater bodies operational. Therefore, often only the larger springs, deep hand-dug-wells or boreholes are reliable across seasons and in drought periods” (Macdonald, 2009:7- 8).

In poor aquifers, an upsurge in demand for water, particularly during excessive dry seasons, can result in increased drawdowns, and consequently an increased unpredictability and risk of failure of water sources (Manu, 2015; Addo, 2010). As demand for water continues to rise as rural population grows, the net effect includes increase in industrial, chemical and domestic waste which can cause reduction in quality and availability of water resources (Ghana Statistical Service-GSS, 2012). Besides, poor drainage, improper waste disposal and increased economic activities such as farming and mining, could result in water pollution, deteriorate the quality of human health and cause damage to facilities used for transportation and delivery of drinking water to rural households (Bazaanah, 2019; GSS, 2010). This affects the sustainability of water resources and increases the burden of water managers to satisfy the average annual rural population’s demand for quality rural water. Therefore, there is the urgent need for communities to adapt to ecological variabilities in order to preserve the ecosystems and the quality of human life. This would require the avoidance of environmental degradation, pollution control and human settlement planning (Bazaanah, 2020). In addition, technology adaptations such as rope and hand pump systems are required to effectively management water resources in order to prevent possible future challenges in rural settings (Calow et al., 2009). In Ghana, the operation and maintenance practices for rural water sources remain poor and many gravity flows schemes and water point sources are not fully operational (Morinville & Harris, 2014).

Moreover, post-construction monitoring, and technical support gaps exist at the district and rural level, with the district water offices focusing more on construction and less on maintenance. The benchmark of the Smart Development Work (2018) indicates that a sustainable water source (piped/borehole scheme) should provide water for a minimum of 350 days in a year with less than 14 days of breakdown. In Ghana, very few water sources (piped/boreholes) are able to meet this standard and a broken-down water source can take up to 12 months or more before it is repaired (Bathsheba, 2011). On average, a water source functions well within the first three years, after which it starts breaking down (Yire, 2015). The majority of rural water sources are not regularly maintained and hence at risk of regular breakdowns, meanwhile, political commitment in construction and maintenance of existing water supply schemes is demonstrated mostly during an election year (Manu, 2015). Beyond the poor culture of maintenance is the lack of transparent and local accountability structures, community sense of ownership and lack of water quality test, especially for water schemes serving rural communities (Bazaanah, 2019). Again, the excessive interference by governments and politicians in rural water supply basically for political expediencies (Addo, 2010) is worrisome. Short-term rural water policies and tariff setting are influenced by politicians (Bohman, 2010), while the selection of beneficiary communities for award of water schemes and membership composition of water boards/committees are riddled with political patronage (Doe, 2007). While significant strides have been achieved in post-construction maintenance of urban water supply facilities, which are periodically rehabilitated by the Ghana Water Company (GWC) in liaison with private operators and Public Utility Regulatory Commission (PURC) (Ministry of Water Resource, Works and Housing-MWRWH, 2011), similar progress are yet to be concretely registered for the rural water supply sector (CWSA, 2015). Drawing from the general comment 15 of the United Nations (2003), this study contends that clean and affordable water is essential human right which is essential for everyday life and development of human populace, regardless of their locations. Yet, in the Northern and Upper East Regions, while population soars, access to affordable water supply and sanitation presents a different narrative and this is more prevalent in rural-poor communities, where the lack of maintenance of water facilities poses a challenge and threat to rural water sustainability (MWRWH, 2012). This could affect the SDGs implementation (United Nations, 2015) and Ghana's vision for achieving universal access to potable water and sanitation for all (MWRWH, 2012). To avoid the effects of water scarcity, the rope-pump technology is offered as a simple technology handpump which has the potential of reducing the cost of installing handpumps in Ghana. A prototype of rope-pump is presented in Figure 1.

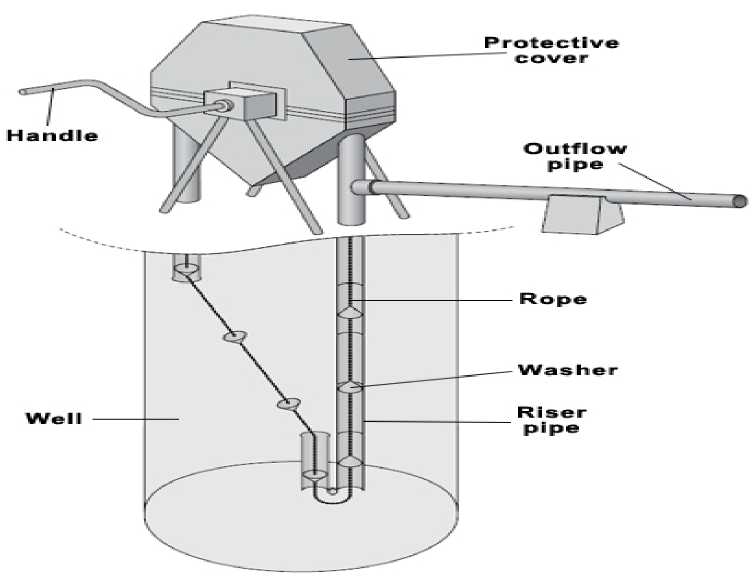

Figure 1: Rope-pump water system
Source: European Union (2013)

From Figure 1, the rope pump technology is a hand operated water lifting device made of locally available materials. It uses washers threaded on a rope to lift water inside a pipe to the surface. The rope is moved by rotation of a wheel handle. The rope pump costs between 75-80% less than the standard pumps currently used in Ghana. It was first introduced on a pilot basis by CWSA in 2000 in Western, Greater Accra, the Northern and Upper East regions (European Union, 2013). As an alternative to pipe-born water systems, the rope and handpumps technology remain feasible and easily adaptable technologies which could help reduce the cost of access to potable water among rural-poor communities (WaterAid Ghana, 2004). This study argues that if well adapted and integrated into the rural water sector, the rope and handpump water technology could become a cost-effective technology compared with the standardized pump and pipe-born schemes. It has the capacity to meet the increasing household water demands of the poor and needy in the rural communities of the Northern and Upper regions of the country.

2. Problem Statement

Standardized handpumps have been in use Ghana for quite some time now. It has been one of the most widely used technologies for the supply of groundwater in most rural parts of the country, especially in the Northern and Upper regions. Despite the wide usage of handpumps, evidence show that only 57 percent of hand pumps are functional, 31 percent are sub-optimally functional, and 12 percent are not functioning at all. With respect to piped schemes, 67 percent of all piped schemes are functional, 4 percent are sub-optimally functional, and 29 percent are not functional (CWSA, 2015). Moreover, the 2016 estimates show that around nine out of ten Ghanaians have access to improved drinking water source, with around 68 percent having access to only basic water services (WHO, 2017; WHO & UNICEF, 2017).

The rural communities where water schemes are either unavailable, non-functional or optimally functional would have to depend on unsafe surface water and or polluted water sources including rivers, dams and rainwater sources for domestic purposes. Over the period of 1990 to 2017, national access to improved water rose by 32 percentage points from 56% to 88%, showing that the national water coverage in Ghana is higher than the regional average. Consequently, rope-pumps are essential for serving families and groups in rural communities (Collaborative Africa Budget Reform Initiative-CABRI, 2017). While the above analysis presents a broadly positive representation on access to potable water delivered through handpumps, it disguises urban-rural disparities, particularly on issues related to reliability, water quality and sustainability. The vast majority of Ghanaians without access to quality water and sanitation services live in rural areas and small towns (Manu, 2015).

In Ghana, although four handpumps, namely Afridev, India Mark II, Nira AF-85, and Vergnet have been standardized for supply of water, coverage in rural areas has stagnated in recent years, driven by climate variabilities, poor service delivery (Mohammed, 2015), pollution and failure to maintain infrastructure (WHO & UNICEF, 2017). Around two-thirds of the installed handpump facilities in rural areas are either completely or partially broken down (Adank et al., 2014). In terms of performance, a handpump is considered "fully functional if water flows within 5 strokes, sub-optimally functional if it takes more than 5 strokes for water to flow and not functional if water does not flow" (CWSA, 2015:1). At the community level, the level of service provided by handpumps are assessed against the national standards (as determined by Ghana Standards Authority) for water quantity and water quality, distance from users, the maximum number of people per handpump (as an indication for crowding), and the reliability of water services (CWSA, 2017). For Adank, et.al., (2014: 2), the service level indicators and minimum standards/benchmarks for handpumps are specified as follows; "Quantity: At least 20 litres per capita per day; Quality: Ghana Standards Authority (GSA) water quality standards (However, for practical reasons, the minimum standard applied is set as "perceived" as acceptable by users'); Coverage: The number of people per handpump should not exceed 300 in case of boreholes and 150 in case of hand-dug wells; Distance: All users should be within 500 meters of the handpump; Reliability: The handpump should provide water for at least 95% of the year, interpreted as at least 347 days of regular service without interruption"(Adank, et.al., 2014: 2). In Ghana, handpumps which meet the standards for all five service level indicators are considered to provide basic services. Handpumps are managed and monitored by the Water and Sanitation Management Teams (WSMTs) for rural communities. The performance standards for WSMTs are assessed against indicators and benchmarks related to governance, operation and financial management capacities. The benchmarks for monitoring and managing hand-pumps are; i) non-political interference, ii) availability of area mechanics services, iii) breakdown repairs and routine maintenance. These indicators are set by the CWSA, based on national policy guidelines and standards regulating community water and sanitation delivery in Ghana (CWSA, 2015). As compared with rope-pump, the technology was first piloted in Ghana by the Community Water and Sanitation Agency (CWSA) in 1990. Although rope-pumps have been in use in rural settlements since 2000, the technology was first transferred from Nicaragua to Ghana between 1999-2000 (Bombas, 2004). Despite the wide usage of rope-pumps, the technology has not been standardized to supply adequate, affordable and clean groundwater to communities. Standardization of rope-pumps would thus mean adaptation of similar standards and management methods as used by CWSA and GSA in the management of handpumps. This study draws on cases from the Northern and Upper East Regions, in order to permit a comparative analysis on the utilization of rope pumps and standardized handpumps to ascertain their performance and make a case for standardization of rope-pumps in order to make water easily accessible and affordable with guaranteed quality for use by rural poor communities.

3. Objectives and Hypotheses

The aim for the study was to compare the utilization of rope-pumps and standardized handpumps to ascertain their performance in rural communities of the Northern and Upper East Regions. In specific terms, this study determined the sanitation and hygiene around the pumps, quality of water delivered by rope-pumps and conventional hand pump, the sustainability and robustness (frequency of breakdowns) of rope-pumps and conventional hand pumps. Moreover, the study determined the popularity of rope pump and that of the standardized pumps among rural households in selected communities. From the objectives, the study estimated the following null hypothesis:

3.1 H_{o1}: there is no significant difference between the robustness of the two types of pumps;
3.2 H_{o2}: there is no significant differences in the sustainability of rope-pumps compared with conventional handpumps;
3.3 H_{o3}: rope--pump do not perform better than conventional handpumps in the communities and finally,
3.4 H_{o4}: there is no significant difference in microbiological (i.e. coliform) water quality between the two pump types.

Sustainability was defined by this study as “intervention which is capable of being supported and maintained by a community or individual over an extended period of time with an absolute minimum of outside assistance” (Wood, 1994). Also, a water supply system is said to be sustainable when it can be financed or co-financed by the users with limited but feasible external support and technical assistance. Moreover, Dayal, Wijk and Mukherjee (2000) discovered that a sustained water supply is one which is regular and reliable and provides enough water of an acceptable standard for at least domestic use. The performance of the pumps is determined by breakdown rate. Breakdowns are rare and repairs are rapid (within 48 hours), and local financing covers at least the regular costs of operation, maintenance (O&M) and repairs. It means that water which is sustainable is at the same time robust. This study determined robustness of the pumps in terms of the pumps ability to continue to function under varying water demand conditions (IRC & CINARA, 1997).

4 Theoretical and Empirical Literature

This study draws from the Technology Acceptance Model (TAM), which serves as the theoretical foundation of technology adoption studies within various socio-economic contexts. Both the theoretical and empirical literature presents sufficient evidence that TAM has an enhanced capability of predicting how people make decisions regarding new technology adoption. TAM has frequently been used for information systems and other fields (Davis, 2000). As such, TAM serves as an appropriate model to use to address consumer acceptance of various technologies. Therefore, TAM is useful when a study focuses on the potential adoption of an emerging technology. This study utilized TAM to predict user acceptance and highlight potential design issues before users of the technology interact with the system (Dillon & Morris, 1996; Mohd, Ahmad, Samsudin, & Sudin, 2011).

TAM was developed with support from IBM Canada (Ajzen & Fishbein, 1980). TAM demonstrates a pioneering research effort by generating a framework for explaining behavioral intentions and actual behavior of users for technology adoption (Yousafzai, Foxall & Pallister, 2007). The efficiency of a technology is determined by its perceived usefulness and perceived ease of use. The perceived usefulness (PU) and perceived ease of use (PEOU) are the perceptions of the beliefs users hold about the technology (Dillon & Morris, 1996). Davis (2000) defined PU as the degree to which a person believes that using a particular system would enhance performance and PEOU as the degree to which a person believes that using a particular system would be free of effort. Venkatesh and Davis (2000), through four longitudinal studies, demonstrated that through the TAM model, interventions could be aimed in advance towards the 52% of variance in usage of interventions and 60% of the variance in use among populations who are less inclined to adopt the technology (Venkatesh & Davis, 2000).

In a related study, Marks, Komive and Davis (2014) found that households participation during technology adoption meetings (p-value = 0.04; $\alpha < 0.01$; n=176), involvement in technical decisions (p-value = 0.6; $\alpha < 0.01$; n=176) and labour contribution to handpump and rope-pump construction (p-value = 0.07; $\alpha < 0.01$; n=176), were each strongly and positively associated with poorer handpump platform infrastructure in both regions. However, handpump infrastructure was likely to provide quality water outcomes when all other variables were else held constant. Similarly, in Kenya, Marks, Onda and Davis (2013) studied the functionality of handpump systems which served between 500 and 8000 rural household populations. The study discovered that due to the dispersed settlement patterns across the population and within the study provinces, handpump water supply reached approximately 60 percent of households in each community. In the case of Ghana, Morinville (2012) and the CWSA (2003) found that the PU and PEOU of water technology are hindered by funding gaps, technical capacities, unavailability of spare parts and human resources. Again, Arlosoroff et al. (1987), Brikke and Bredero (2003) found standardized pumps to have recorded a maximum pumping head of 75m. In contrast, Harvey and Drouin (2006) found the average maximum flow rates of 10m delivery head was recorded as 28 l/min for the standardized handpump and 41 l/min for the rope-pump.

5 Study Areas and Methodology

5.1 Description of the Study Areas

The study area falls within two regions, namely the Upper East and Northern regions. The Upper East region is bounded to the west by the Upper West region, to the north by Burkina Faso, to the east by Togo, and to the south by the Northern region. The Northern region is also bounded by Ivory Coast to the west, Upper East and Upper West to the north, Brong Ahafo region to the south and Togo to the east. The study was carried out in five communities, namely Damweo, Saboro and Nalgukania in the Upper East region and Piriga and Nayoku in the Northern region. From figure 2, Damweo is located in the south-eastern part of the Bolgatanga Township of the Upper East region, within longitudes 0°50'55"W and 0°51'20"W and latitudes 10°46'18"N and 10°46'40"N. It is bounded by Sawaba to the east, Zongo to the north, SSNIT flats to the south and Zongo No. 1 to the west (see figure 2). Piriga and Nayoku., located within Walewale township. Piriga lay roughly within longitude 0°47'7"W and latitude 10°19'55"N whiles Nayoku roughly lay around longitude 0°47'19"W and latitude 10°21'13"N (See figure 2). (West Mamprusi District Profile, 2012). Damweo has a total population of 1,363, composed of males (655) and females (708) (Ghana Statistical Service-GSS, 2010). The population for Piriga and Nayoku is 1,979 (population projected from 2000PHC), composed of 49.2% male and 50.8% females. Piriga is more populous (1016) than Nayoku (963) (GSS, 2012). In figure 2, the fourth and fifth study communities were the Nalgukania (1,356 population) and Saboro (1,232 population), are located in the Navrongo township. Nalgukania is located roughly within longitude 1°5'58.063"W and 1°6'20.275"W and latitudes 10°52'43.507"N and 10°52'17.918"N. It is bounded by Gonia to the north, Korania to the south and Nosinia and Bonia to the east and west respectively. Saboro on the other hand is located roughly within longitude 1°5'46.309"W and 1°6'55.544"W and latitude 10°54'24.631"N and 10°54'31.277"N bounded by Kayilo to the north, Namolo east to the east, Namolo west to the west and Nosinia to the south. (See figure 2). The study communities generally have gentle slopes with isolated rock outcrops and uplands which have slopes (GSS, 2012). The main type of soil present in the communities is the groundwater laterite. The groundwater laterites are developed mainly over shale and granite. Due to the underlying rock type (granite), they become waterlogged during the rainy season and dry out during the dry season, thus causing cemented layers of iron-stone (hard pan), which makes cultivation difficult. The study communities have no rivers, but smaller streams exist, and they are underlined by Birimian rocks and granite. The groundwater in the communities is laterite, due to impervious iron pan or clay pan in the sub-soil. The areas are often characterized by waterlogs at the peak of the rains, resulting in perennial floods (GSD, 2009). The climates of the communities are classified as tropical, with two distinct seasons, namely a wet season and a dry season (GSS, 2012: GSS, 2012).

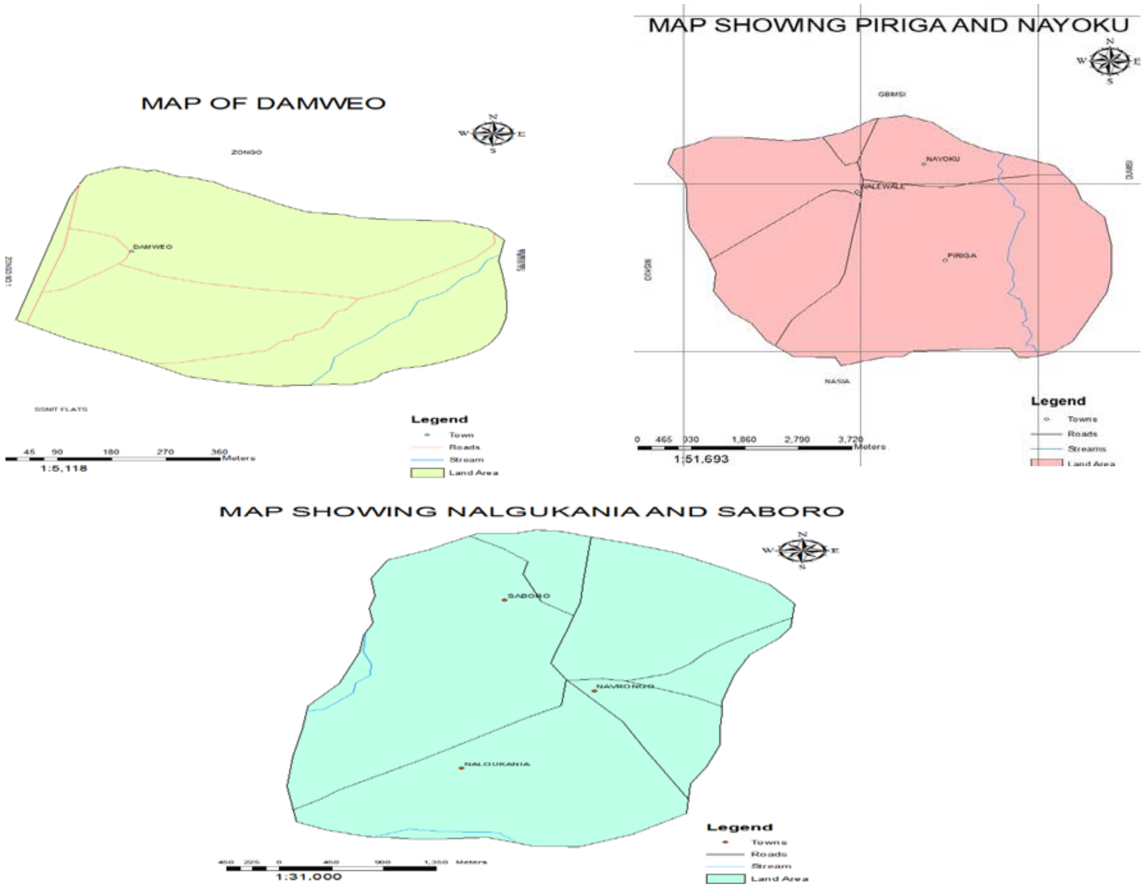

Figure 2: Map of the rural areas covered by the study

Source: Geological Survey Department-GSD (2009)

The natural vegetation of the communities is that of the guinea savannah woodland, consisting of short deciduous trees, widely spaced and a ground flora, which gets burnt by fire or scorched by the sun during the long dry season, characterized by the Harmattan winds which blow across the Sahara Desert. The most common economic trees are the shea nut, dawadawa, and baobab. The primary sources of water supply in the communities are pipe systems, boreholes fitted with handpumps, hand-dug wells fitted with rope-pumps as well as unprotected hand-dug wells. Streams, ponds, and dugouts which exist in the community are primarily used as water sources for animal farming. Pipe-borne water are present in some households which can afford them whiles other households resort to hand-dug wells fitted with rope-pumps and the handpump fitted boreholes (Kassena Nankana East District-KNED, 2012). Meanwhile, the disposal of wastewater constitute major environmental and public health problems in the communities. All the communities are not properly drained, and therefore, wastewater generated from bathing are normally collected around houses. Since no soakaways are constructed, it increases the breeding of mosquitoes which causes malaria. The communities lack toilet facilities, hence open defecate is generally common. Solid waste generated in the settlements are managed by open dumping and incineration, causing environmental pollution and increase in diseases such as cholera and typhoid among residents in the communities (GSS, 2010).

5.2 Methodology

In planning the research approach, data collection, and analysis, the study utilized several procedures. The study adopted the cross-sectional design and the post-positivist paradigm, which was generally structured along the quantitative research approach (Walliman, 2018). These strategies were utilized to allow an objective study comparative analysis of the performance of rope-pump and standardized handpumps in the communities. Cross-sectional design enabled the selection of respondents across a section of the population at a pre-defined time (Babbie, 2016). Moreover, post-positivism paradigm ensured precision in the sample estimation and allowed objectivity in the evaluation of the objectives and hypotheses of the study (Neuman, 2014). Also, drawing from Mugenda (2003), the profile of the study area was reviewed and communities within the study area where rope-pumps and standardized handpumps existed were purposively chosen in order to permit a comparative analysis. The five case study communities, namely Damweo, Saboro, Nalgukania, Piriga, and Nayoku were selected based on the availability and utilization of rope-pumps as well as standardized handpumps. The total number of pumps in the study area is 24 with rope pumps and standardized handpumps being 14 and 10 respectively. Ten water quality samples were taken due to financial constrains at the time of undertaking the project. The water sources were not evenly distributed within the communities where research was conducted. Due to the diverse uses of water sources, rope pumps were basically for households while handpumps were mainly for the use of the populace of the communities without any water sources such as pipe systems or rope pumps in their homes. In order to determine the quality of drinking water i.e. bacteriological quality delivered by rope-pumps and standardized handpumps, a total of ten (10) water samples were taken from all the five (5) communities.

A 300ml water sample was taken each for a rope-pump and a standardized handpump. Water from the pumps which have been idle for a while, were taken after water from the pumps has been allowed to run for 20 to 30 seconds. The samples were cooled and filtered immediately after sampling and were transported to the laboratory for microbiological analysis. Since previous research had indicated a significant relationship between microbiological contamination of shallow groundwater and rainfall, especially depth of rainfall in the previous 48 hours (Howard et al., 2003), it was important that this variable was considered when taking samples for analysis. The gathering of data about the sustainability and robustness of the pumps mainly occurred through directed interviews administered to 10 opinion leaders, 2 from selected from each of the five communities. The sustainability of a pump is the ability of the pump to withstand and endure continued pressure of usage. Sustainability is a very complex and difficult parameter to ascertain since different people have diverse ways of determining the sustainability of a pump. However, for this study, the parameters used in the determination of the sustainability of the pump were robustness of the pumps, flow rate of the pumps, availability of spare parts and easy access to technical expertise. The robustness of the pumps was measured from the frequency in breakdown of the pumps in the communities within the study area in the given year of the research. The total head of the rope pump was determined by measuring the total length of the rope within the pump which aids in the transport of the water to the surface and dividing the length by two (2). However, since drilling data was not available for drilled borehole with standardised handpumps, the total head was estimated from the type of hamdpump installed since it provides the maximum depth at which a standardised handpump type can draw water from a borehole. Standardised handpumps installed on boreholes in Ghana is dependent on the depth of the borehole, that is shallow boreholes between 0m to 16.5m have the Nira standardised handpump installed while the Afridev is installed on boreholes with depth between 16.5m to 30m (CWSA, 2011). The flow rates of the rope pumps and standardized handpumps was calculated by the amount of water obtained from the pump after a minute of pumping. Self-designed questionnaires were prepared and administered in each of the community. The questionnaires aimed to collect information about the construction of the well, the acceptance of the pumps by the community, the uses of water, the maintenance system, the costs, and the frequency in breakdown.

Table: 1. Communities and corresponding sample size.

Community	Total Population (N)	Sample size (n)
Damweo	1363	93
Saboro	1232	92
Nalgukania	1356	93
Nayoku	963	90
Piriga	1016	91
Total	5930	459

The groups targeted for administering the questionnaire were individuals household members between the ages of 18-60, who used these pumps as sources of water. The total sample size for the study was 559, which composed of 459 household respondents and 10 purposively selected opinion leaders, comprising two leaders from each of the communities. The choice and selection of opinion leaders was based on their foreknowledge on water and sanitation situation in the communities. Besides, the opinion leaders are the mouthpiece of the communities and had much more information on whatever goes on in the communities and could furnish the us with the necessary information needed for the research. Also, the rope pumps where basically for household use and the landlords were the main point of information regarding the rope pump. The sample size for the households was calculated based on the formula: $= \frac{\boldsymbol{N}}{\boldsymbol{1+N(\alpha)^2}}$, where, n = sample size, N= total population of the communities, α= margin of error. A confidence level of 90%, representing a 10% marginal error was used in estimating the sample size for the various communities. The total sample size selected from Damweo was calculated as follows : $\boldsymbol{n} = \frac{\boldsymbol{N}}{\boldsymbol{1+N(\alpha)^2}} = \frac{\boldsymbol{1363}}{\boldsymbol{1+1363(0.1)^2}} = \frac{\boldsymbol{1363}}{\boldsymbol{1+1363\ (0.01)}}$; hence n = 93. This sample calculation procedure was repeated in the selection of the remaining communities. As illustrated by Table 1 and based on the sample size formula, the study utilized 459 household samples, composed of Damweo (93), Saboro (92), Nalgukania (93), Nayoku (90) and Piriga (91). The simple random sampling technique (Babbie 2016) i.e. the lottery method was utilized for selecting of the units of analysis from the various sub-groups/ stratum from each of the communities. These techniques allowed the respondents in each population sub-group to have equal and fair chances of being represented in the study (Hacker, 2014). The data collected were analyzed and compared with the World Health Organization (2006) standards to ascertain whether the bacteriological quality of the water is good for use by the community members. In order to weigh the influence of external parameters on the results, correlations were statistically analyzed (Pallant, 2013) using the presumptive count of the total coliform counts as the dependent variable. The independent variables considered were the type of pump, location (i.e. community), depth of the well, time period since the last rain, age of the pump, time period since the last cleaning of the well and number of users. At 95% confidence interval and with tolerated error margin of 5% (e) = 0.05, the decision rule for the hypothesis test was stated as: accept the null hypothesis (H_o) if p-value is greater than or equal to ($\geq$) the alpha-value (α) of 0.05, and do not accept H_o if p-value is less than (<) the assumed alpha value (α) of 0.05. Furthermore, statistical analysis was then conducted to compare the respective influences of the rope-pumps and the conventional standardized handpumps on microbiological water quality. In order to test the actual differences between the two sets of data, the Independent Sample T-test was utilized (Cresswell, 2014). As a first step, the distribution of log median value of the thermotolerant coliform counts for the conventional standardized pumps and for the rope-pumps had to be tested for normality using the Probability Plots Correlation Coefficient test (Gronmo, 2019). The sustainability, robustness and total head of rope-pumps and standardized handpumps, were used in the comparative analysis using the Statistical Product for Services and Solutions (SPSS) version 25 software (Pallant, 2013). The annual breakdown rate data for the rope pump as well as the standardized handpumps was tested for normality using the probability plot test. It showed that the data did not follow a normal distribution. Hence, the non-parametric design which is the Mann-Whitney Wilcoxon's rank-sum test (Bernard, 2011) was used to determine whether there was a significant difference in annual breakdown rate between the rope-pump and standardized handpumps in the communities.

6 Results and Discussion

6.1 Gender, Location and Perceptions on Utilization of Rope/Handpumps.

From Table 2, the questionnaires retrieved from the respondents from the five communities were less than the initial total sample size of 559. The response distribution based on community location and gender showed about 431 respondents participated in the study, translating into a response rate of 77%. The difference in the participation among the respondents could probably be attributed to the timing when the fieldwork was conducted. The communities are predominantly agrarian, and the fieldwork occurred in the rainy season, a period where most residents are often busy with farming activities and therefore, were not mostly available at home for the interviews.

Table 2: Gender, location and perceptions on rope and handpump use in the communities

	Utilization of rope-pump and handpump					
Community	Male	(%)	Female	(%)	Total	(%)
Damweo	33	8	47	11	80	19
Saboro	44	10	42	10	86	20
Nalgakania	44	10	46	11	90	21
Piriga	42	10	45	10	87	20
Nayoku	46	11	42	9	88	20
Total	209	48	222	52	431	100

In Table 2, the findings suggest that a little above half (52%) of the respondents were females and 48% were males. The relatively higher female participation was perhaps due to the perceived gender roles attached to water in the Northern and Upper Ease Regions, where females are traditionally perceived to be responsible for domestic responsibilities of fetching water and maintaining sanitary environment at the household level. It suggest that the capacity of females towards maintenance and interpretation of drinking water quality is essential for ensuring good health and adequate hygiene around handpump and rope-pumps water sources in the communities. In terms of gender, both male and females generally perceived that both the rope and handpump technology were useful in the communities as reliable sources of households drinking water. Community members are more inclined to use both technologies as sustainable sources of water (Venkatesh & Davis, 2000). A positive perceived usefulness (PU) and perceived ease of use (PEOU) among users of the technology (Dillon & Morris, 1996) is likely to result in change in attitudes, possible technology adaptation and sustainability of water supply in the communities.

6.2 Water and Sanitation Facilities

The communities are equipped with pipe systems, boreholes fitted with handpumps, hand-dug wells fitted with rope-pumps as well as unprotected hand-dug wells. These are the water sources from which members of the communities obtain water for their daily needs. From Table 3, the results showed Damweo had one (1) standardized handpump, a number of houses were also connected to the nations pipe borne water system. There are also four (4) rope pumps in Damweo as well as two (2) unprotected wells, pond, and dugouts. About 2% of the respondents from Damweo had access to pipe-born water. Majority of the respondents (80%) confirmed that there were two (2) public KVIP's in Damweo with some houses having water closets and pit latrines. Similar to GSS (2010), about 50% of the respondents in Damweo perceived that open defecation was still prevalent among residents in the community. Again, from Table 3, the finding showed Saboro community had two (2) standardized handpumps, three (3) rope pumps, and only 3% of the households had access to pipe-born water. About 95% of the respondents confirmed that the community did not have public place of convenience. Only a few households (10%) had access to pit latrines while most people (90%) living in the community adhered to open-air defecation. From Table 3, Nalgakania had three (3) standardized handpumps and four (4) rope-pumps. About 8% of the respondents confirmed that only a few houses had access to pipe-born water, meaning, most of the residents obtained their sources of drinking water mostly from rope-pumps and standardized handpumps. Most of the respondents confirmed (86%) that there were no public toilets in the community. Under these compelling conditions, there is no option for most residents (77%) of the community but for open defecation. Furthermore, the study found that Piriga was relatively equipped with two (2) standardized handpumps, unprotected well with the use of rope and bucket and two (2) broken down rope-pumps which were not in use, hence, all the community members utilized water from the unprotected wells and standardized handpumps for their daily needs (see Table 3). Most of the respondents confirmed that there was only one public toilet serving the community, with only a few households having pit latrines. Open defecation was perceived to be very common (84%) practice at Piriga since places of convenience were perceived to be inadequate. From Table 3, the findings raises public health concerns (WHO, 2006; WHO, 2017), the need to intensify education on environmental health and hygiene promotion around drinking water sources in the community (CWSA, 2017). Similarly, the findings showed the people in Nayoku had their source of water from two (2) standardized handpumps and three (3) unprotected wells. The only rope-pump available in the community had broken down due to lack of maintenance (See Table 3). With respect to sanitation, 85% of the respondents confirmed the community was beset with inadequate toilet facilities. Apart from the relatively rare individual household latrines, there was just one community latrine for the 962 residents of Nayoku– and it is not always in operation in times of flooding. This situation compels most of the residents (92%) to practice open defecation.

Table 3: Water sources and toilet facilities in the communities

Community	Respondents' perceptions					
	No. of dug wells/ rope pump	No. of boreholes standardized handpump	Type of standardized handpump	Pipe water access (%)	Limited public toilet facility (%)	Practice of open defecation (%)
Damweo	4	1	Afridev	2	80	50
Saboro	3	2	Afridev and Nira AF-85	3	95	90
Nalgakania	4	3	Afridev and Nira AF-85	8	86	77
Piriga	2*	2	Afridev (2)	0	73	84
Nayoku	1*	2	Afridev (2)	5	85	92

**Broken down*

In general, access to pipe-born water was limited. This is perhaps due to the cost of maintenance and inability to pay for user fees. As an alternative to pipe-born water supply, the rope and handpumps technology remain feasible and easily adaptable technologies which could help reduce the cost of access to potable water among rural-poor communities (WaterAid Ghana, 2004). Again, the findings in Table 3 imply that access to basic water, toilet facilities still remains a luxury for residents living in the communities. Open defecation was a common practice due to lack of improved public toilets. The consequences of this practice on the health of residents are enormous, forcing them to pay a heavy price for healthcare. Beside polluting the environment, open defecation causes perilous problems arising from ill-health. High levels of open defecation are linked to child mortality, poverty, and disparities between rich and poor (WHO & UNICEF, 2017). Similarly, Calow et al. (2009) admonishes the need to avoid environmental degradation and adapt to technologies such as rope and handpump systems in order to forestall possible future water challenges in rural settings. Adank et al. (2014) also found that around two-thirds of the installed handpump facilities in rural areas are either completely or partially broken down.

6.3. Hygiene Around Pump Facilities

The physical state and hygiene around both rope and handpumps under the study were further determined in order to establish whether the pumps were close to a latrine or any other source of pollutant including waste dumping site, stagnant water or poor drainage channels around the wells, which could pollute the communities' drinking water sources. Although a 10m radius is recommended by the WHO (2006; 2017) and CWSA (2015) as standard distance between water sources and toilet/refuse dumps, at the Damweo community, the study found rope-pumps were sited closer to public toilets. The distance from the rope-pump to the community latrine was 8.5m. The standardized hand pumps were however not located nearer to any source of pollution at the time of the survey. Similarly, Saboro had rope-pumps closer to a latrine. Approximately, the distance from the rope-pump to the latrine was 7.3m. None of the standardized handpumps in the area was situated near a pollution source. However, there were incidences of poor drainage channels causing stagnant water around one of the boreholes fitted with standardized handpump in the community. In contrast, there were no cracks nor hygiene problems with both the rope and handpumps in the Nalgukania community. There were no latrine, refuse dumping site, cemetery nor toilet facilities nearer to the pumps, an indication that the residents were perhaps aware of the 10m radius stipulations and standards of the CWSA. At both Piriga and Nayoku, the survey found that the drainage channels in both communities were destroyed causing water stagnation around the pumps and boreholes. The location of these water sources could cause pollution of the water utilized by both communities. In contrast, no hygiene problems were detected at any of the pumps in the Nalgukania community. This is perhaps due to awareness of water safety and maintenance environmental hygiene surrounding water sources in the community. From the findings, the study deduced that the benefits of having access to improved drinking water sources in the communities can only be fully realized when there is also access to improved sanitation and adherence to good hygiene practice (WHO & UNICEF, 2017) around the rope and handpumps water sources. This is because contaminated water causes many water-borne infections like diarrhoea, and also serves as a carrier for vectors such as mosquitoes spreading epidemics (KNED, 2012). Drawing from the TAM model (Dillon & Morris, 1996), the findings of this study demonstrated that the continued use of both rope and handpumps in the communities was an indication of user acceptance of both technologies (Mohd et al., 2011).

6.4 User Related Issues

In terms of user access, there was a remarkable difference between the two pump types in terms of the number of populations which directly had access to water from both pumps. This proved the assumption that rope-pumps can serve only family groups rather than entire rural communities (CABRI, 2017). The findings showed that the number of users per rope-pump for each of the communities in the study areas were between 150-300 population. This is perhaps because rope-pumps were being used primarily by families, households and their immediate neighbourhoods. In contrast, handpumps served on average between 500-1500 population per each of the communities. This disagree with the World Health Organization (WHO, 2006: WHO, 2017) standards, which prescribed that a standardized pump should serve 250-300 people in a community. The standardized standardized pumps and the rope-pump were all perceived as technologies for potable rural water supply as compared to rainwater or unprotected hand dug wells that communities had been using and still continue to use for other house chores. During rush hours, which is early in the mornings and at sunset, the pumps are mostly crowded with people especially women and children who come around to fetch water. This crowding mostly occurred around the boreholes fitted with standardized handpumps since it serves the whole community other than the rope-pumps which serve only households and families. From Table 3, the main types of standardized handpumps utilized in the communities were the Nira AF-85 and the Afridev (Mohammed, 2015). Unlike rope-pumps, the flow rate of the standardized handpumps were also low between 16 l/min and 20 l/min. The corresponding pumping heads supplied between 0-30m of water per withdrawal from both pump types. However, the time spent at both pumps to fill a bucket depended on the flow rates as well as the abrupt lowering of the water level. On average, the waiting period for water to rise before pumping was between 15-40minutes. The users of handpump tend to walk between 10-15minutes of distances in order to fetch water compared with residents who utilized rope-pumps as main sources of water and who in most cases did not have to walk for long to water source. Although both pump types continued to serve as reliable sources of rural water supply, the findings showed there were no standards for rope-pumps (CWSA, 2015), unlike handpumps which were assessed against the national standards for water quantity and water quality, distance from users, the maximum number of people per handpump (as an indication for crowding), and the reliability of water services (CWSA, 2017). Again, the findings disagree with Adank et.al. (2014) who discovered the "number of people per handpump should not exceed 300 and 150 in the case of rope-pumps/hand-dug wells. In terms of distance, all users should be within 500 meters of the handpump" (Adank et al., 2014: 2).

6.5 Technical Performance

The analysis on the technical performance of the pumps revealed that the pumping head for the rope-pumps varied between 16m and 25m. For deeper installations especially above 40m the rope pump has to be installed in a drilled hole rather than a hand-dug well. This indicates that the rope pump has great diversity than the standardized pumps as a low-lift pump for domestic water supply. The maximum depth of standardized handpumps in the communities was less than 75m. The findings disagree with Arlosoroff et al. (1987), Brikke and Bredero (2003) who found standardized pumps to have recorded a maximum pumping head of 75m. In contrast, Harvey and Drouin (2006) found the average maximum flow rates of 10m delivery head was recorded as 28 l/min for the standardized handpump and 41 l/min for the rope-pump. This indicates that the rope-pumps had a comparative advantage, since it was able to deliver water at approximately 1.5 times the rate of the Nira.

Table: 4. Total head and corresponding flow rates of rope-pumps and standardized pumps.

Community	Rope-pump pumping per head {R.P T/H (m)}	Rope-pump flow rate {R.P F/R (l/min)}	Standardized Handpump pumping per head {S.P T/H (m)}	Standardized Handpump flow rate {S.P F/R (l/min)}
Damweo	18	30.09	16.5-30	24.26
Saboro	16.4	32.47	16.5-30	24.86
Nalgakania	25	25.02	0-16.5	29.98
Piriga	-	-	16.5-30	22.47
Nayoku	-	-	16.5-30	23.32

From Table 4, the study found that rope-pumps at Damweo with pumping heads of 18m had flow rate of 30.09 l/min and standardized handpumps of 16.5-30m recorded flow rate of 24.26 l/min. This indicated that the rope-pumps were 1.47 times faster than the rate of the standardized handpump. Similarly, at Saboro, rope pump of 16.4m had flow rate of 32.47 1/min and standardized handpumps 16.5-30m had a flow rate of 24.86 1/min, an indication that the flow rate for rope-pumps were on average better as compared with the handpumps. Based on the technical output and capacity of rope-pumps technology, the findings support European Union's (2013) argument for enabling structures at the national, local government and private sector levels to develop rope-pump technology and standardize its operation as alternative source of rural water supply.

6.6. Robustness of Pumps

The robustness of the pumps was measured from the frequency in breakdown of the pumps in the communities within the study area in a given year which is 2012. From Table 5, the study introduced a new pump system robustness index for optimizing the pumps design and operation in order to ensure effective rural water distribution system. The breakdown rate was taken as the robustness indicator and incorporated as a constraint in a pump design and operational model that minimized the total pump's operation. As illustrated by Table 5, the finding showed that in Piriga and Nayoku, the breakdown rate for handpumps were relative higher compared with rope-pumps in 2012. The reasons could be due to lack of maintenance culture or availability of technical personnel or high cost of spare parts for the handpumps technology. In contrast, however, the showed that for Damweo, Saboro and Nalgakania, there were no remarkable variations/differences in the rates of breakdown between handpumps and rope-pumps. Handpumps and rope-pumps in Damweo, Saboro and Piriga appeared to be more robust that those in Nalgakania and Nayoku.

Table 5: Average breakdown rate of the pumps and year of breakdown

Community	Standardized Handpump	Rope-Pump	Total	Year of Breakdown
Damweo	1	1	2	2012
Saboro	1	1	2	2012
Nalgakania	2	2	4	2012
Piriga	1	0	1	2012
Nayoku	2	0	2	2012
Total	7	4	13	2012

The distribution of the breakdown rate values for the pumps was tested for normality using the probability plot (PP). Pallant (2013) argued that where the p value is low (e.g., ≤ 0.05), you conclude that the data do not follow the normal distribution. In this study, the findings showed that all the set of data did not follow a normal distribution, since its p-value (0.026) was less than the alpha value of 0.05 at a confidence limit of 95%. The probability plot is shown in Figure 3. Comparatively, findings from Table 5 and figure 3 confirmed earlier studies by Morinville (2012) and the CWSA (2003) which found that in Ghana, the PU and PEOU of water technology are hindered by funding gaps, technical capacities, unavailability of spare parts and human resources. From figure 3, since the data did not follow a normal distribution, the comparison between the two sets of data was therefore conducted using a non-parametric test, namely the Mann-Whitney Wilcoxon's rank-sum test. The first null hypothesis (H_{o1}) assumed that "there is no significant difference between the robustness (i.e. breakdown rate) of the two types of pumps" against an alternative hypothesis that assumed that "there exist a significant difference between the robustness (i.e. breakdown rate) of the two types of pumps". The test was conducted using the mean of the breakdown rate as an outcome measure for each pump type.

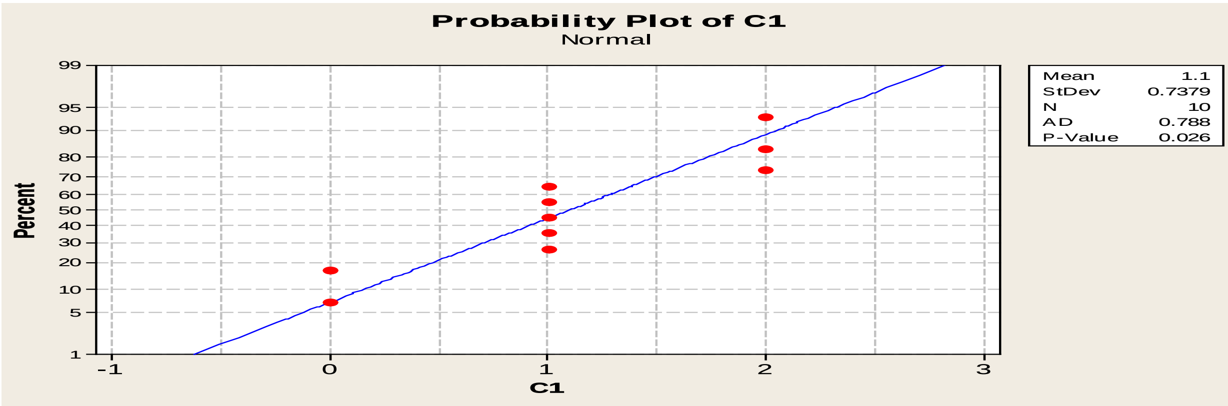

Figure 3: Probability plot distribution on rate of pumps breakdown

As illustrated by Table 6, with 95% confidence and 1 degree of freedom (df), the findings showed that with the standardized handpumps, the p-value was 0.2123 which was comparatively greater than (>) the alpha-value (α) of 0.05. In terms of the rope-pumps, with 1 degree of freedom (df), the p-value was 0.1341 which was also found to be greater than the alpha-value (α) of 0.05. The findings indicated that the first null hypothesis (H_{o1}) remained valid and therefore, should be accepted.

Table 6: Outcome of Mann-Whitney Wilcoxon's rank-sum test

Type of Pump	n	Mean ($\bar{X}$)	Test statistic	df	p-value
Standardized Handpump	7	1.40	0.1431	1	0.2123
Rope Pump	4	1.33	0.1220	1	0.1341

The study therefore concluded that there exists no significant difference in the breakdown rate of handpumps and rope-pumps in the five communities. In comparison with earlier studies, the present study disagree with Marks et al (2013) who found handpump water systems to have capacities of easily reaching out to relatively poorer households in rural communities. Bathsheba (2011) also discovered that in Ghana, a broken-down water source can take up to 12 months or more before it is repaired. Similarly, Morinville and Harris (2014) and Manu (2015) reports that the operation and maintenance practices for rural water sources remain poor and many gravity flows schemes and water point sources are not fully operational.

6.7. Sustainability and Performance of Pumps

The sustainability of a pump is the ability of the pump to withstand and endure continued pressure of usage. Sustainability is very a complex and difficult parameter to ascertain since different people have diverse ways of determining the sustainability of a pump. However, for this study, the parameters used in the determination of the sustainability of the pump were robustness of the pumps, flow rate of the pumps, availability of spare parts and easy access to technical expertise. Considering the robustness indicator, the breakdown rate of both pumps was compared and from the above analysis, the p-values of 0.2123 and 0.1341 obtained were found to be greater than the alpha value (α) of 0.05 at 95% confidence level. Hence, the null hypothesis that there was no significant difference between the robustness of the two pumps remained valid and therefore, was accepted by the study. The findings confirmed the second null hypothesis (H_{o2}) which assumed that there is no significant different between the sustainability of the two pumps. From, the third null hypothesis (H_{o3}) the study assumed that "rope-pump do not perform better than conventional handpumps in the communities". The findings showed that the rope-pumps were 1.47 times faster than the standardized handpump in terms of flow rate. The rope pumps recorded flow rates of 30.09 l/min and the standardized handpump 20.45 l/min. Therefore, the third null hypothesis r of the study remained valid and was accepted. In terms of availability of spare parts, the study found that the rope-pump required more regular maintenance and repair than the standardized pumps. This is because the rope-pumps needed oil to ease the operation of the handle and also there was early wear of the rope. However, since there was availability of spare parts, repairs could be undertaken relatively quickly and cheaply which was not perceived as a major constraint. No particular preference between the two pump types was expressed by any of the respondents. In terms of easy access to technical expertise, the findings showed that since the rope-pumps were manufactured locally, technical expertise were readily available to deal with broken down pumps. This made it possible for rope pumps to be repaired within the shortest possible time. Even though there exist some village based maintenance team, not all the communities had these experts to deal with broken down standardized handpumps. Broken down pumps mostly took more than 48 hours for repairs to begin. This implies that with regards to availability of technical expertise, the rope-pump outperforms the standardized pump. The findings confirm Dayal et al. (2000) who discovered that a sustained water supply is one which is regular and reliable and provides enough water of an acceptable standard for at least domestic use. Breakdowns are rare and repairs are rapid (within 48 hours), and local financing covers at least the regular costs of operation, maintenance (O&M) and repairs.

6.8 Microbiological Water Quality

In determining the microbiological quality of the water from both pumps, the study was initially planned to collect ten (10) water samples from the five selected communities, two (2) water samples each from a community. One sample was taken from the rope-pump and another from the standardized handpump. However, during the field survey, six (6) water samples were collected. This was because two communities Piriga and Nayoku had their rope-pumps broken down, hence water samples was taken from Damweo, Nalgukania and Saboro. The collected samples were taken to the Ghana Urban Water Limited Laboratory (GUWLL) in an ice pack and then analyzed using MacConkey Broth Media to test for the total coliform level in the water. The water was then incubated at a temperature of 37.5° C for 24 hours. The total coliforms for each sample recorded are outlined in Table 7. The findings showed that with the exception of Damweo, all the other test tube results for both rope-pump and standardized handpumps remained positive across all the selected communities. The positive coliform was an indication of the existing of unacceptable water quality for human consumption. It implied either human or animal wastes were entering the water supplied by both pumping technologies utilized by the communities. The positive results could be attributed to pollution around the water sources. Every effort should be made to achieve a drinking water quality as safe as possible. It is important for the CWSA, government and private sector to quickly identify all water contaminants and treat them before they do irreversible damage to the increasing population of the communities, whose daily survival are dependent on water from both types of pumps.

Table 7: Microbiological analysis for total coliform (5-tube MPN method)

Water Sample	No. of Tubes Tested Positive	MPN Index (Total coliform/100 ml)
Damweo Rope Pump	3	9.2
Damweo Standardized Pump	0	< 2.2
Saboro Rope Pump	3	9.2
Saboro Standardized Pump	1	2.2
Nalgakania Rope Pump	5	>16
Nalgakania Standardized Pump	5	>16

From figure 4, the distribution of the total coliform values for the pumps (see Table 7) was tested for normality using the Probability Plot (PP). As illustrated by figure 4, the p-value (0.414) for all the data set was found to be less than (<) the alpha value of 0.05 at a confidence level of 95%, which meant that all the set of data for both pumping devices did not follow a normal distribution. Consequently, the distribution of the values for the pumps were tested for normality, using the Probability Plot (PP) as illustrated by Figure 4.

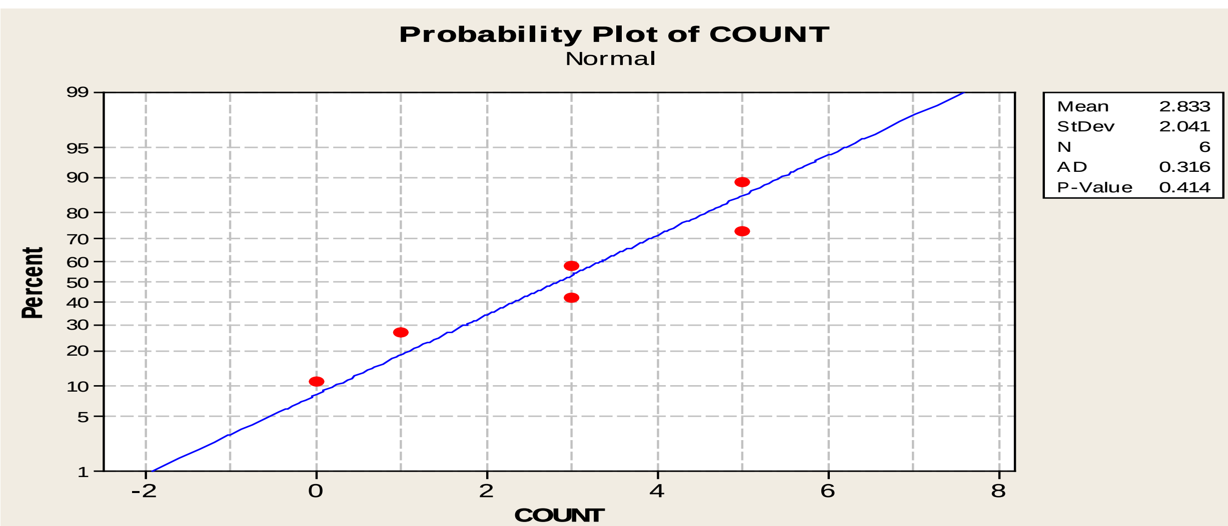

Figure 4: Probability plot distribution of total coliform

From figure 4, the p-value (0.414) of the test statistic was greater than (>) the alpha value of 0.05 at 95% confidence limit. This provided a sufficient indication that the set of data were normally distributed. Hence, the comparison between the two sets of data was conducted using a parametric test, namely the independent sample t-test. The fourth null hypothesis (H_{o4}) assumed that "there is no significant difference in microbiological (i.e. total coliform) water quality between the two pump types" against an alternative hypothesis which stated that "there exist significant differences in microbiological (i.e. total coliform) water quality between the two pump types". The test was conducted using the mean of total coliform as an outcome measure for each pump type.

Table 8: Outcome of independent sample T-test

Pump type	n	Mean ($\bar{X}$)	Test Statistic	p-value
Standardized Handpump	3	2.333	-1.000	0.374
Rope-pump	3	3.67	-1.230	0.478

From Table 8, the study found that the p-values for standardized handpumps and rope-pumps were 0.374 and 0.478 respectively. Since the p-values were greater than (>) the alpha value of 0.05 at 95% confidence limit, the fourth null hypothesis (H_{o4}) which assumed there is no significant difference in the total coliform between the rope-pumps and standardized handpumps remained valid and was therefore accepted. The study concluded there is no significant difference in total coliform between the pump types utilized by residents in the communities. Even though the use of the rope pump does not pose any negative impacts on the environment, there is the potential for negative health impacts through secondary contamination from the rope. As a result, wear and tear from winding the wheel resulted in the rope particles breaking into the water. Water could also drain back into the wells resulting in contamination. The findings affirm the assumption of poor operation and maintenance culture which is prevalent in the rural water sector (Morinville & Harris, 2014). The continuous use of rope and handpumps was an indication of PU and PEOU of both technologies in the rural communities (Dillon & Morris, 1996; Davis, 2000). However, to improve the quality of water supplied by both pumps, there is the need to avoid environmental degradation through ecological policy measures for pollution control and human settlement planning in order to forestall possible future challenges in rural settings (Calow et al., 2009). This is because contaminated water sources are found to be the causes for many water-borne infections like diarrhea (WHO & UNICEF, 2017; KNED, 2012).

7. Conclusions

The analysis shows that there are no significant differences in microbiological water quality between the two pumps types. There are no significant differences in robustness between the two types of pumps. The pumping heads of the two pumps types was justified to be different. With relative flow rates of the two pumps, the rope-pumps outperformed the conventional handpumps. The rope pump outperforming the standardized pump was not based on the coliform count but rather based on parameters of the sustainability and performance of the pumps. In three out of four criteria used in determining sustainability (i.e., flow rate, availability of spare parts and technical expertise), the rope pump outperformed the standardized handpumps. In general, the rope-pump technology can be standardized and adapted as a pump for water supply in the five communities since there were no significant difference between the rope-pump and standardized handpumps. Rope-pump technology is feasible, sustainable, scalable and will meet user needs if adapted for use by the communities. Measures for technology adaptation and pollution control will remarkably improve water quality from both rope and handpumps installed in the communities. Since rope-pumps are not approved, the CWSA and district level training packages for water and sanitation system operators do not include those who operate and maintain rope pumps. If rope-pump use is to be scaled up at the rural level, the suitability of the technology for use on boreholes, in addition to shallow wells, needs to be better understood. It should also be trialled with smaller numbers of users at household level or in clusters of households. From the findings, the study concludes that the PU and PEOU of water technology in the rural communities are hindered by funding gaps, technical capacities, unavailability of spare parts and human resources. The communities continual use of rope-pumps highlights their intentions, acceptance and actual behavior of users, thus, emphasizing the need to standardize and adopt both technologies to augment rural water supply.

8. Recommendations and Policy Implications

There is the need to draw together all actors involved in rope-pump technology introduction in order to address lapses in technology transfer including promotion to stimulate demand, improve relationships between communities and the manufacturers, secure relevant private sector investment and political will to invest in the rural water sector. The attitudes of both regulators/facilitators i.e. the Water and Sanitation Team members, the District/Municipal Assemblies, officials of the CWSA, environmental health officers (EHOs), and users will have to change if the technology is to be scaled-up in the communities. To improve water quality, rope-pump and handpump technologies should qualify for government subsidies and investment just as pipe-born water technologies do. Again, technical capacities must be built, and financial sources for producers should be improved upon in order to promote and market rope-pump technology. To achieve this, technical, financial and user information on rope-pump technology must be compiled and made easily accessible to stakeholders. The flow rate of water from the rope-pumps may be faster yet short-lived. Therefore, the study recommend future studies to compare the quantity of water and duration of flow per technology to see if the rope pump meets the per capita Basic Water Requirement (BWR).

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